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1 Description

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3 Optical Module and Optical System

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5 The invention relates to an optical module including a  
6 circuit carrier, a housed semiconductor element which is  
7 arranged on the circuit carrier, and a lens unit for  
8 projecting electromagnetic radiation onto the semiconductor  
9 element, wherein the housed semiconductor element and the  
10 lens unit are formed in two parts.

11

12 The invention also relates to an optical system including an  
13 optical module which is formed in this way.

14

15 Optical modules and systems of the type in question are used  
16 in motor vehicle technology in particular.

17

18 Electromagnetic radiation from various frequency ranges can  
19 be used in this context, wherein, in addition to the visible  
20 light by means of which applications such as Lane Departure  
21 Warning (LDW), Blind Spot Detection (BSD) or Rear View  
22 Cameras typically function in the external environment of a  
23 motor vehicle, infrared radiation which is invisible to  
24 humans is particularly preferred in the case of applications  
25 in the internal environment of a motor vehicle, such as Out  
26 of Position Detection (OOP), or in the case of additional  
27 external lighting for a Night Vision System.

28

29 Stringent requirements exist in the case of applications in  
30 the interior or exterior of a vehicle, due to external  
31 effects such as temperature, humidity, contamination and  
32 vibration. The typical service life of a system in a vehicle  
33 is 10 to 15 years, wherein only extremely low failure rates

1 are tolerated, and therefore only very slow aging is  
2 permissible in the components of an optical system of the  
3 type cited at the beginning.

4  
5 Since the installation space of optical modules or optical  
6 systems is very restricted in many cases, additional  
7 difficulties exist in the implementation of said optical  
8 systems. Using conventional means, it is therefore extremely  
9 difficult to construct a hermetically sealed and reliable  
10 unit comprising a camera chip (CCD or CMOS sensor) and an  
11 optics system.

12  
13 In order for a camera system consisting of an image sensor  
14 (currently CCD or CMOS) and a lens system to achieve an  
15 adequate sharpness of image, the sensor and optics  
16 components must be compatible with each other in a manner  
17 which is geometrically very accurate. The tolerance range  
18 for the distance from camera chip to optics system in the z-  
19 axis is usually in the range of a few hundredths of a  
20 millimeter, in order to achieve an optimally sharp image for  
21 a specific focal depth range. This is problematic for so-  
22 called fixed-focus systems in particular, since these may be  
23 at best moderately subject to tolerances during  
24 manufacturing. An offset of the camera chip in relation to  
25 the optics system in the x-axis or y-axis also has the  
26 consequence that the optical system "squints" under certain  
27 circumstances, i.e. the image is cut off at one edge  
28 (horizontal or vertical) in each case because no more pixels  
29 are present there as a result of the offset, and said pixels  
30 should be available for precautionary reasons.

31  
32 A further problem is presented by so-called "tilt", i.e. a  
33 tilting of the camera chip about the x-axis or y-axis,

1 causing the image to exhibit unsharpness gradients in a  
2 horizontal or vertical direction. It is also possible for  
3 "rotation" to occur, i.e. a rotation about the z-axis of the  
4 camera chip in relation to the optics system.

5  
6 Nearly all of the camera systems which are currently  
7 available on the market and are supplied with a fixed focus  
8 setting require a further tuning step during manufacturing,  
9 in which step the distance from the camera chip to the  
10 optics system along the z-axis is set and fixed at this  
11 value. This is done e.g. by means of a thread and a  
12 corresponding locking screw or an adhesive bond. A tuning  
13 step might also be required for the x-y offset or, if this  
14 does not take place, a correspondingly bigger sensor which  
15 equalizes the tolerances via an increase in pixels can be  
16 provided. Software calculation and calibration of the  
17 "rotation" is also known. Since the available information is  
18 sharp in other respects, the pixels merely have to be  
19 reassigned in a kind of "calibration process". However, it  
20 is not possible for any more information to be present at  
21 the edges or corners, since these have been cut off.  
22 Finally, a purely mechanical reduction of "tilt" and  
23 "rotation" between chip and optics system in the case of  
24 normal systems can generally only be achieved by high-  
25 precision manufacturing and assembly or by a tuning of  
26 components.

27  
28 For reasons of cost and aspects of quality assurance,  
29 however, it should be possible to produce cameras for  
30 specific low-cost applications, such as e.g. automotive,  
31 industry, digital cameras, mobile phones, toys, etc., with a  
32 minimum of adjustment operations between optics system and  
33 camera chip, i.e. without performing focus settings in

1 relation to the optical surface of the CMOS or CCD sensor.  
2 This essentially conflicts with the cited requirements.

3

4 One possibility for developing a focus-free system is to  
5 reduce the total number of possible tolerances and elements,  
6 such that the module or system functions without adjustment  
7 at least within a specific range of distances and  
8 temperatures by virtue of its design. When using the  
9 invention e.g. in the context of a passenger protection  
10 system in a motor vehicle, to which the present invention is  
11 not restricted, however, it should be possible to guarantee  
12 sharp images at distances of e.g. 15 cm to 130 cm and at  
13 temperatures of e.g.  $-40^{\circ}\text{C}$  to  $+105^{\circ}\text{C}$ . The fewer the elements  
14 in the tolerance chain, the more readily this can be  
15 implemented. In the case of housed semiconductor elements, a  
16 large part of the tolerance chain relates in particular to  
17 the required soldered joints and possibly adhesive joints or  
18 similar between chip and circuit carrier.

19

20 By using only one lens, it is possible to avoid giving rise  
21 to additional optical tolerances as a result of a  
22 complicated lens structure. The lens holder itself, which is  
23 preferably made of plastic, can be connected to the lens  
24 assembly in various ways, such that it is always possible to  
25 ensure an exact optical alignment of the lens assembly and  
26 the semiconductor element in relation to the lens holder or  
27 the lens assembly.

28

29 However, in the case of systems which to a large extent  
30 exhibit a conventional structure comprising objective and  
31 camera chip, wherein the camera chip or semiconductor  
32 element is deposited in a housing on a suitable circuit  
33 carrier, it is difficult to circumvent the cited problems in

1 their entirety and at the same time satisfy the cited  
2 quality requirements. In fact, special measures need only be  
3 adopted against extraneous light radiation or other  
4 environmental effects from the front in the case of housed  
5 semiconductor chips, since the chip housing offers an  
6 adequate protection from the rear e.g. for the silicon which  
7 is transparent for IR radiation. However, the objective  
8 itself must be aligned with the camera chip and exhibit a  
9 defined focusing. This currently takes place using locking  
10 possibilities which are subject to tolerances, e.g. by  
11 screwing, adhesive bonding or similar, by means of which the  
12 objective is fixed relative to the camera chip on the  
13 circuit carrier.

14  
15 The invention addresses the problem of providing an optical  
16 module and an optical system comprising a housed  
17 semiconductor element which is arranged on a circuit  
18 carrier, in which the possible tolerance chain is minimized  
19 such that, in the context of simple and inexpensive  
20 assembly, a reliable optical quality can be provided without  
21 alignment effort and particularly without focusing effort,  
22 and that said quality can be maintained over the service  
23 life of the module or system. Moreover, necessary measures  
24 against extraneous light radiation or other environmental  
25 effects from the front should be eliminated as far as  
26 possible.

27  
28 This problem is solved by the features in the independent  
29 patent claims. Advantageous embodiments of the invention,  
30 which can be implemented individually or in combination with  
31 each other, are specified in the dependent claims.

32  
33 The invention builds on the optical module of the type in

1 question, in that a support is formed, at least in sections,  
2 on the housing of the semiconductor element, and a lens unit  
3 is arranged on and supported by said support. This is easy  
4 to implement especially when using molded plastic housings,  
5 since in addition to the shape of the actual housing, the  
6 edge region in particular can be configured almost without  
7 restriction, in particular as a defined reference layer and  
8 in particular in relation to the chip. In this way, the  
9 tolerance range which is available for the focusing is kept  
10 as small as possible, such that it now comprises only  
11 manufacturing tolerances of the support and the lens unit.  
12 Furthermore, the proposed solution has the advantage that,  
13 as a result of the direct contact of lens unit and housed  
14 chip, the lateral ingress of extraneous light is largely  
15 prevented.

16  
17 According to the invention the support is preferably formed  
18 as a ring collar, which is however at least partially tilt-  
19 free, whereby not only is the distance and therefore the  
20 focusing range advantageously kept within the required  
21 dimensions, a tilting of the components in relation to each  
22 other is also reduced to a minimum.

23  
24 In a first development of the invention, the lens unit  
25 includes a base lens, wherein the support of the lens unit  
26 takes place via the base lens. This is advantageously done  
27 in such a way that a design for the base lens is selected  
28 which includes a surface section that is formed so as to  
29 correspond to the support, e.g. is plane at least in  
30 sections, wherein said surface section is positioned on the  
31 supports which are formed on the housing of the  
32 semiconductor element.

1 In an alternative development of the invention, the lens  
2 unit includes a lens holder, wherein the support of the lens  
3 unit takes place via the lens holder. This is advantageously  
4 done in such a way that a design for the lens holder is  
5 selected which includes a surface section that is formed so  
6 as to correspond to the support, e.g. is plane at least in  
7 sections, wherein said surface section is positioned on the  
8 supports which are formed on the housing of the  
9 semiconductor element. Because the support extends further  
10 outwards, the support on the lens holder advantageously  
11 further reduces risk of tilting. It also allows the  
12 formation of smaller modules than modules having a support  
13 via a base lens.

14  
15 According to the invention, the base lens or the lens holder  
16 advantageously has a collar, at least in sections, which is  
17 part of the lens and is formed so as to correspond  
18 essentially to a locating face which is formed on the  
19 support. This is easy to implement especially when using  
20 molded plastic lenses, since in addition to the optically  
21 effective surface of the lens, irrespective whether this has  
22 a conventionally curved or plane form, the edge region can  
23 be configured almost without restriction, in a similar  
24 manner to the chip housing according to the present  
25 invention.

26  
27 In a particularly preferred embodiment, a locating face is  
28 formed on the support, at least in sections. The locating  
29 face can be non-conical or, in a development of the  
30 semiconductor element, tapered and in particular conical  
31 considered in the direction of the optical axis of the  
32 module. In such a configuration, a type of self-centering  
33 can advantageously occur, thereby ensuring an exact

1 positioning of the optics system in relation to the chip  
2 with reference to the x-axis and y-axis as well as reducing  
3 the "tilt" to a minimum.

4

5 The invention also consists of an optical system including  
6 an optical module of the type cited above. In this way, the  
7 advantages of the optical module also become valid in the  
8 context of an overall system.

9

10 The invention is based on the discovery that by forming, at  
11 least in sections, a support directly on the housing of a  
12 housed semiconductor element, even in the case of  
13 conventionally housed semiconductor chips where  
14 (independently of the optics system) only the component for  
15 a standard SMD is loaded, a camera module can be constructed  
16 in which it is possible to dispense with any mechanical  
17 focus setting. Fully automatic manufacturing of the module  
18 is therefore possible, having the advantage that the  
19 manufacturing and assembly costs are reduced in the case of  
20 large numbers of units. Furthermore, the optical module can  
21 be developed without active parts such as threads or locking  
22 screws, thereby resulting in greater reliability. As a  
23 result of the limited tolerances in the construction,  
24 including in the x-axis and y-axis, the chip surface need  
25 not be unnecessarily large, thereby making the camera chip  
26 cheaper. The construction of such a module can be configured  
27 to be relatively compact, which is advantageous in that the  
28 camera module can also be used in applications that are  
29 subject to conditions of limited space. Finally, the  
30 integrative construction also advantageously offers  
31 protection against extraneous light radiation.

32

33 The invention is particularly useful in the implementation

1 of video systems, possibly in combination with radar  
2 systems, ultrasound systems or the like in the field of  
3 motor vehicles.

4

5 The invention is now explained by way of example with  
6 reference to preferred embodiments and with reference to the  
7 accompanying drawings in which, schematically,

8

9 Fig. 1 shows a sectional view of an optical module  
10 according to the invention;

11

12 Fig. 2 shows a magnified section X of the module as per  
13 Fig. 1;

14

15 Fig. 3 shows a semiconductor element which is formed in  
16 accordance with the invention.

17

18 In the following description of the preferred embodiments of  
19 the present invention, identical reference signs designate  
20 identical or comparable components.

21

22 Using different sections and perspectives, Figures 1 to 3  
23 show an optical module including a circuit carrier 10, a  
24 housed (packaged) semiconductor element 12 which is arranged  
25 on the circuit carrier 10, and a lens unit 14, 16, 18, 20,  
26 21 for projecting electromagnetic radiation onto the  
27 semiconductor element 12. The lens unit 14, 16, 18, 20, 21,  
28 which is formed separately from the housed semiconductor  
29 element 12, comprises a lens holder 14 and a lens assembly  
30 16, 18, 20, 21 including at least one lens 20 and possibly  
31 an aperture 21.

32

33 The invention provides for a support 13a to be formed, at

1 least in sections, on the housing 13 of the semiconductor  
2 element 12, and the lens unit 14, 16, 18, 20, 21 to be  
3 arranged and supported on said support 13a. The support of  
4 the lens unit 14, 16, 18, 20, 21 takes place either via the  
5 lens 16, which is preferably formed as a so-called base lens  
6 16, or the lens holder (not shown). In this regard, base  
7 lens 16 or lens holder feature, at least in sections, a  
8 surface section 16a which is formed so as to correspond to  
9 the support 13a, has a plane form by way of example in the  
10 figures, and is positioned on the support 13a which is  
11 formed on the housing 13 of the semiconductor element 12.  
12 Moreover, the base lens 16 or the lens holder features, at  
13 least in sections, a collar 16b which is formed so as to  
14 correspond essentially to a locating face 13b which is  
15 formed on the support 13a. The support 13a is therefore  
16 preferably formed in the shape of a ring collar 13a. The  
17 locating face 13b of the ring collar 13a is preferably  
18 conically formed considered in the direction of the optical  
19 axis 33 of the module, such that it is advantageously  
20 easier, not just for automated manufacturing, to achieve a  
21 type of self-centering of adjacent components, in this case  
22 lens 16 and support 13a.

23  
24 Provision is preferably made for a lens assembly 14, 16, 18,  
25 20, 21 including a plurality of lenses 16, 18, 20 and  
26 possibly at least one aperture 21 in the form of a housing.  
27 The optical quality can be improved by means of an objective  
28 including a plurality of lenses, this also being possible in  
29 the context of the present invention, in particular because  
30 it is possible to work with small tolerances. In this  
31 context, it is also particularly advantageous that the  
32 lenses 16, 18, 20 and possibly the aperture 21 are in direct  
33 contact with each other. This practically excludes

1 variations in the lens assembly 16, 18, 20, 21 in a z-  
2 direction, i.e. in the direction in which the lenses are  
3 sequential. The tolerances are now only dependent on the  
4 lens assembly 16, 18, 20, 21 itself. It is likewise  
5 particularly useful that the relative positions of the  
6 lenses to each other are determined by the geometry of the  
7 lenses 16, 18, 20 and possibly apertures 21 themselves. The  
8 arrangement of the lenses in an x-y direction can also be  
9 determined by the lenses themselves, namely by configuring  
10 the locating faces of the lenses or apertures  
11 correspondingly.

12  
13 The lenses 16, 18, 20 or apertures 21 which are held in the  
14 lens holder 14 are therefore advantageously formed in such a  
15 way that they assume a defined position relative to each  
16 other within the lens holder 14. Furthermore, at least one  
17 of the lenses 20 is configured in such a way that it engages  
18 with the lens holder 14 and therefore also occupies a  
19 defined position relative to the semiconductor element 12.  
20 In this way, all lenses 16, 18, 20 are aligned relative to  
21 the semiconductor element 12.

22  
23 In addition, this alignment is not jeopardized as a result  
24 of the lens holder 14 being connected to the circuit carrier  
25 10, e.g. via a screw connection 23. The housed semiconductor  
26 element 12 is arranged on the circuit carrier 10 via lead  
27 frames 30. Provision can also be made for an adhesive joint  
28 22 or other known connection methods.

29  
30 It is particularly useful that just one of the lenses or  
31 apertures is directly in contact with the lens holder (not  
32 shown). Since the lenses determine their relative positions  
33 among themselves, it is sufficient to fix a single specific

1 lens or aperture to the lens holder. In this way, the whole  
2 lens assembly is oriented in relation to the semiconductor  
3 element, whereby ultimately the advantageous optical quality  
4 can be guaranteed. In this context, it is particularly  
5 advantageous if the single specific lens is connected to the  
6 lens holder in a waterproof and dust-proof manner. It is  
7 advantageous if the uppermost lens is selected as the lens  
8 which engages with the lens holder for sealing purposes.  
9 This can be achieved by connecting the single specific lens  
10 to the lens holder by means of ultrasound bonding, laser  
11 welding or adhesive bonding, for example, alternatively or  
12 additionally using screws and/or a cementing compound in  
13 some cases.

14  
15 Provision can also be made for the lens assembly to be  
16 snapped via catching means (likewise not shown) into the  
17 region holding the lenses. This can also ensure that exact  
18 positioning is achieved. It should also be emphasized that  
19 this option ensures simpler separation possibilities between  
20 the lenses and the remaining components, in particular the  
21 expensive semiconductor element. The sealing effect can be  
22 provided in a particularly advantageous manner, particularly  
23 in the context of a snap-in assembly, if the lenses feature  
24 a hard and a soft component, wherein the soft component is  
25 arranged at the circumference of the lens for the purpose of  
26 sealing. The soft component also satisfies the general  
27 requirement that the lenses must not be subjected to any  
28 stresses when they are snapped in; stresses would always  
29 result in an adverse effect on the optical properties.

30  
31 The lens assembly 16, 18, 20, 21 is preferably held in the  
32 lens holder 14 by means of a holding element 15 (molded  
33 ring). The holding element 15 preferably has a hard

1 component 15a and, at least in sections, a permanently  
2 elastic component 15b. A permanently elastic component 15b,  
3 which is preferably circumferentially formed, can be used in  
4 particular for sealing the lens assembly 16, 18, 20, 21  
5 against humidity and contamination at the same time - in  
6 addition to its specific function of offsetting any stresses  
7 which may occur due to mechanical and/or thermal conditions.  
8 The permanently elastic component 15b is preferably formed  
9 on the circumference which fits against the lens 20. In the  
10 region of the harder component 15a, the holding element 15  
11 is arranged on the region 14 which holds the lenses, e.g. by  
12 means of ultrasound bonding, laser welding, adhesion,  
13 riveting, molding, or other connection method which is  
14 similarly easy to automate. Screw connections and snap-in  
15 connections are also conceivable. The hard component 15a of  
16 the holding ring 15 preferably comprises a thermoplastic  
17 material. A permanently elastic component 15b which  
18 preferably comprises thermoplastic elastomers (TPE) or  
19 silicone or similar has proven itself accordingly. For the  
20 purpose of providing an integrated and easily manageable  
21 component 15, the permanently elastic component 15b is  
22 preferably molded onto the hard component 15a or vice versa,  
23 e.g. using a two-component injection method.

24  
25 Furthermore, the prevention of undesired optical effects,  
26 particularly due to lateral light ingress, by means of  
27 blackening and/or matting or by using total reflection (not  
28 shown) can be particularly advantageous. These are examples  
29 of suitable measures.

30  
31 Finally, the invention usefully allows the module to be  
32 connected to, particularly soldered onto (e.g. by means of  
33 hot-bar soldering), a rigid circuit board (these are also

1 known as rigid-flexible systems) via a flat cable or in  
2 particular by means of a flexible PCB if this is used as a  
3 circuit carrier. This is a particularly flexible solution  
4 for connecting the circuit carrier 10 or the module to a  
5 control unit or circuit board (not shown).

6

7 As a result of the formation, at least in sections, of a  
8 support 13a directly on the housing 13 of a housed  
9 semiconductor element 12, the invention allows the  
10 construction of a camera module in which it is essentially  
11 possible to dispense with any mechanical focus setting.  
12 Fully automatic manufacturing of the module is therefore  
13 possible, this having the advantage that the manufacturing  
14 and assembly costs are reduced in the case of large numbers  
15 of units. In particular, the optical module can be developed  
16 without active parts such as threads or locking screws,  
17 thereby resulting in greater reliability. Furthermore, as a  
18 result of the limited tolerances in the construction,  
19 including in the x-axis and y-axis, the chip surface need  
20 not be unnecessarily large, thereby making the camera chip  
21 cheaper. The construction of such a module can be configured  
22 to be relatively compact, which is advantageous in that the  
23 camera module can also be used in applications that are  
24 subject to conditions of limited space. Moreover, the  
25 construction offers the possibility of devising a  
26 hermetically sealed module which is well protected against  
27 environmental effects such as humidity or dust.

28

29 The features of the invention, which are disclosed in the  
30 present description, in the drawings and in the claims, can  
31 be essential for the realization of the invention, both  
32 individually and in any combination. The invention is  
33 particularly suitable for applications in the interior

1 and/or exterior of a vehicle.

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3